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## Occupational exposure to air pollution and cancer risk among Danish urban mail carriers

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**Abstract Objectives:** Our objective was to study the risk of cancer associated with exposure to air pollution among mail carriers. **Methods:** We carried out a retrospective cohort study of 17,233 persons who had been mail carriers during the period 1898–1996. Data on employment was obtained from company files. Data on cancer was obtained from the Danish Cancer Registry. **Results:** Male mail carriers employed for more than 3 months had a low incidence of cancer, standardised incidence ratio (SIR) 0.92. For cancers related to air pollution the risk estimates were 0.96 for lung cancer, 0.91 for laryngeal cancer and 0.98 for bladder cancer. A significant low risk for cancer of the oesophagus (SIR 0.50), kidney (SIR 0.73), prostate (SIR 0.81) and skin (melanoma) (SIR 0.87) was seen. Among female mail carriers the risk pattern showed a significant excess of cancer of the cervix uteri (SIR 2.24). **Conclusion:** In our study of mail carriers who had spent most of their day doing physical hard work outside in the general air pollution we saw no excess in cancers related to air pollution compared with the general population of Copenhagen. This might be due to the protective effect of physical activity.

**Keywords** Epidemiology · Air pollution · Cohort study · Mail carriers

### Introduction

Air pollution consists of a complex mixture of organic and inorganic compounds, many of which are genotoxic and potentially carcinogenic. Health effects associated

specifically with traffic-related air pollution have been studied mainly in workers exposed to high concentrations of vehicle exhaust fumes. Studies of tunnel workers (Evans et al. 1988), ferrymen (Ulfvarson et al. 1987; Ulfvarson and Alexandersson 1990), garage workers (Ulfvarson and Alexandersson 1990; Gamble et al. 1987), mail carriers (Zuskin et al. 2000; Hansen 1990), street cleaners and cemetery workers (Raaschou-Nielsen et al. 1995) showed an association between air pollution and the prevalence of respiratory diseases. Furthermore, studies have shown that urban populations have an increased risk of several cancer forms compared with rural populations (Nyberg et al. 2000; Friis and Storm 1993; Hemminki and Pershagen 1994; Schouten et al. 1996).

Mail carriers spend 80%–90% of their working day outdoors delivering mail. Therefore, they are highly exposed to environmental air pollutants. Work has been divided into categories, from very easy work to very heavy work. Delivering mail is classified as moderately heavy work to heavy work (Jørgensen et al. 1983). Therefore, mail carriers not only spend much time on the streets but they also perform physically heavy work, thereby inhaling more of the polluted air. It has been shown that ventilation can increase by up to 25 times when a person is doing hard physical work (Åstrand and Rodahl 1977).

Urinary levels of polycyclic aromatic hydrocarbon (PAH) metabolites have been evaluated as indicators of PAH exposure, and 1-hydroxypyrene appears to be a relevant urinary metabolite (Jongeneelen et al. 1988). Table 1 shows the mean levels of 1-hydroxypyrene in Danish workers. For administrative employees in a bus company and for workers without known occupational exposure the levels were 0.05  $\mu\text{mol/mol}$  creatinine and 0.06  $\mu\text{mol/mol}$  creatinine, respectively. Among non-smoking bus-garage workers and mechanics the level was 0.11  $\mu\text{mol/mol}$  creatinine, and for iron foundry workers exposed to a low level of PAH the level was 0.17  $\mu\text{mol/mol}$  creatinine. The level for non-smoking mail carriers was as high as 0.29  $\mu\text{mol/mol}$  creatinine. This level was obtained even though mail carriers were

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**Table 1** Urinary 1-hydroxypyrene in Danish workers

Occupation	Mean 1-hydroxypyrene ( $\mu\text{mol/mol}$ creatinine)	Smoker	Reference
Administrative employees in a bus company	0.05	No	Nielsen et al. 1996
Workers without known occupational exposure to PAHs	0.06 <sup>a</sup>	Yes/no	Hansen et al. 1995
Bus garage workers, mechanics	0.11	No	Nielsen et al. 1996
Foundry workers	0.17 <sup>a</sup>	Yes/no	Hansen et al. 1995
Mail carriers	0.29	No	Hansen et al. 1998
Bus drivers	0.62	Yes	Hansen et al. 1998

<sup>a</sup>95% One-sided tolerance interval

outside in the air pollution for only half of the working day. Thus, for a whole working day the level of 1-hydroxypyrene in non-smoking mail carriers corresponded to smoking bus drivers.

We performed a study on urban mail carriers to investigate the risk of cancer associated with exposure to air pollution.

## Methods

In Denmark personal and occupational data on employees in public companies are usually reliable, as such information often underlies future pension payments. The delivery of mail in Denmark has, since 1624, been carried out only by Post Denmark, which is a public company. On the basis of two sources we established a cohort that consisted of urban mail carriers. Firstly, all mail carriers who had stopped working at a Copenhagen post office during the period 1898–1996 were retrieved from the main archive in Post Denmark. Information about name, date of birth or personal identification number, place of birth, and start and end of work periods was computerised. Of the 11,994 people initially registered, 41 (0.3%) were excluded due to duplicate registrations or—in a few cases—obviously incorrect data. The excluded data were distributed equally over the whole period. Secondly, all employees who had been working as mail carriers in Copenhagen on the 1st of January 1997 were registered in an electronic personnel archive from which we obtained relevant data. Information was obtained on 9,272 employees, of whom 14 were excluded because their age at first employment was below 14 years, 291 were excluded because they were employed, e.g. as mechanics, and 3,329 were excluded because they worked indoors at post offices. We registered the shortest employment period for 61 persons who were registered manually in the main archive as well as electronically. After the exclusions we had information on 5,577 mail carriers. By combining the data from the two sources we had information on 17,530 mail carriers.

We used the Central Population Register (CPR) to obtain information on vital status and migration. The CPR had been established in Denmark in April 1968, and all citizens were assigned a unique 10-digit personal identification number that included six digits for the date of birth. People who could not be found in the CPR

were assumed to have died before 1 April 1968. The National Death Index, which dates back to 1943, was consulted for the date of death of these people. We excluded 295 mail carriers (1.7%) mostly born in the 1800s as we could not obtain information on date of death. Twenty workers who had emigrated after 1968 and two persons who died on the day they started work as a mail carrier were excluded as well. This left 17,233 mail carriers (14,568 men and 2,665 women).

Due to the urban–rural gradient in cancer incidence we obtained up to seven addresses of a randomly weighted sample of 156 persons registered in the main archive. For 97%, place of residence was Greater Copenhagen. We could not find any addresses for the remaining people. For the cohort that consisted of electronically registered mail carriers we had the latest postal number of the residence. Ninety-six percent of these electronically registered mail carriers were living in Greater Copenhagen.

Since January 1943, incident cancers have been reported to the Danish Cancer Registry. We used computerised record linkage to identify incident cancers among mail carriers with personal identification numbers (mail carriers alive at 1 April 1968). The remaining group was linked on the basis of name and dates of birth and death, and each match was verified by hand. The period of follow-up for cancer began on the date of first employment with Post Denmark or 1 January 1943, whichever occurred last. The period ended on the date of death or 31 December 1997, whichever occurred first. Cancers were classified according to a modified version of the International Classification of Diseases, Seventh Revision (ICD-7). We applied national incidence rates for all tumour categories, calculated according to gender, age, and calendar period (in 5-year groups), to the person-years of observation to obtain the number of cancers expected had the mail carriers experienced the same incidences as the general population of Copenhagen. To allow for latency we used the intervals covering up to 14 years, 15–29 years and more than 30 years of exposure lag, defined as the number of years between first employment as a mail carrier and the day of the diagnosis. These periods were chosen because no cancers are supposed to have developed during the first 14 years of employment and calculations have shown that the lag period did not change the conclusions. Therefore, only the calculations for the given lag periods are shown.

The statistical tests were based on the assumption that the observed number of cancer cases in any specific category follows the Poisson distribution. Tests of significance and 95% confidence intervals (95% CIs) were calculated for the standardised incidence ratio (SIR) as the ratio of the observed to expected cancers.

## Results

The total cohort of 17,233 mail carriers consisted of 14,568 men and 2,665 women, and 399,199 person-years of observation were accumulated over, on average, 23.2 years (range 62 days–84 years). The characteristics of the cohort are shown in Table 2.

Overall, 1,686 cancers were diagnosed among mail carriers, with 1,814 expected yielding a significantly low SIR of 0.93. Table 3 shows the results for men and women employed for more than 3 months. The risk of air-pollution-related cancers was as expected [lung (SIR 0.96), larynx (SIR 0.91) and bladder (SIR 0.98)]. Significantly low SIRs in all cancers (0.92), oesophagus (0.50), kidney (0.73) and prostate (0.81) were seen among men when compared with the expected numbers of cancers based on the cancer rates for the Copenhagen population. Female mail carriers had a significantly excess risk of cancer of the cervix uteri (SIR 2.24).

We saw a low SIR for all cancers among people employed between 1940 and 1959, but no change in the risk of lung cancer when the mail carriers were grouped according to period of first employment (Table 4). There

was no effect of duration of employment (data not shown).

In Table 5 the mail carriers are divided into “time since first employment”. The risk of cancer among mail carriers in the 30-years latency group was significantly low for all cancers and three specified cancer sites. The risk of cancer after 20 years of employment was low when a latency time of 30 years was included.

## Discussion

In this study of urban mail carriers we found that those who had been employed for more than 3 months had significantly low cancer rates. Copenhagen mail carriers are exposed to the general level of air pollution in a city with 1.1 million inhabitants. However, spending most of the day close to streets makes them breathe more air pollution than one normally breathes as a city dweller. Moreover, they perform physically hard work with increased respiration when they deliver mail, either walking or bicycling; motor vehicles are used only by mail carriers in the country.

The risk of cancers related to air pollution (lung, bladder, and larynx) (Cohen 2000; Boffeta and Silverman 2001; Soll-Johanning et al. 1998) was as expected, with SIRs of approximately 1. An evaluation of the effect of outdoor air pollution on an increased risk of lung, larynx and bladder cancer is complicated by other carcinogenic exposure, such as active and passive smoking. We did not have any data on smoking. However in 1990, 1995 and 2000 the Danish Work Environment Cohort Study was conducted, and that study showed that out of approximately 50 male mail carriers, 38%, 30%, and 38% were smokers, respectively (Burr, National Institute of Occupational Health, Denmark, personal communication, 2001). Two surveys (Hansen 1990; Jørgensen et al. 1983) based on 430 and 301 Danish mail carriers showed that 55% and 61%, respectively, were smokers. That is the same smoking prevalence as among the Copenhagen population. The prevalence of smokers in Denmark has decreased considerably during the past decades: in 1970, 1987, and 1997 the prevalences were 68%, 50%, and 38%, respectively (Hannerz and Tüchsen 2001).

There are no studies on mail carriers and cancers related to air pollution, but in a study from 1971 and onward, of work-related cancers in the Nordic countries (Andersen et al. 1999), it was found that postal and communication workers had a lung cancer risk of 1.04 in Denmark, 0.75 in Finland, 0.79 in Norway, and 1.21 in Sweden. It was not possible, however, to distinguish between postal workers working indoors and outdoors and communication workers.

Workers whose jobs keep them outside for some or all of the day, e.g. mail carriers, are at particular risk of skin cancer (Rattenbury 2000). Andersen et al. (1999) showed that postal and communication workers had a significant excess of skin cancer. However, we showed

**Table 2** Descriptive characteristics of 17,233 Danish urban mail carriers

Characteristic	Number	Percent
Male	14,568	85
Female	2,665	15
First employment		
1898–1919	1,087	6
1920–1929	119	11
1930–1939	701	4
1940–1949	1,845	11
1950–1959	1,912	11
1960–1969	2,411	14
1970–1979	2,426	14
1980–1989	3,127	18
1990–1996	3,605	21
Duration of employment (years)		
< 0.25	709	4
0.25–< 1	2,340	14
1–< 2	2,084	12
2–4	2,916	17
5–9	2,105	12
10–14	1,602	9
15–19	807	5
20–29	1,222	7
30–39	1,938	11
40+	1,510	9
Total	17,233	100

**Table 3** Risk of cancer among Danish male mail carriers employed for more than 3 months

Site	Mail carriers			
	Observed	Expected <sup>a</sup>	SIR	95% CI
<b>Male</b>				
All malignant	1,589	1,722	0.92	0.88–0.97
Tongue	11	8	1.31	0.65–2.35
Lip	8	8	0.97	0.42–1.91
Mouth	19	16	1.16	0.70–1.81
Pharynx	24	22	1.08	0.69–1.61
Oesophagus	15	30	0.50	0.28–0.83
Stomach	80	78	1.03	0.81–1.28
Colon	115	117	0.99	0.81–1.18
Rectum	88	88	1.00	0.80–1.23
Liver	29	24	1.21	0.81–1.74
Pancreas	39	49	0.80	0.57–1.09
Larynx	32	35	0.91	0.62–1.28
Lung	298	310	0.96	0.86–1.08
Kidney	41	56	0.73	0.52–0.99
Bladder	136	138	0.98	0.82–1.16
Prostate	109	134	0.81	0.67–0.98
Testis	37	44	0.85	0.60–1.17
Skin non-melanoma	212	243	0.87	0.76–1.00
Skin melanoma	245	282	0.87	0.76–0.98
Brain	43	50	0.87	0.63–1.17
Thyroid	6	5	1.27	0.46–2.77
Leukaemia	44	41	1.08	0.78–1.45
Other and unspecified	64	72	0.89	0.67–1.13
<b>Female</b>				
All malignant	73	69	1.06	0.83–1.34
Colon	2	3	0.76	0.08–2.73
Rectum	1	1	0.78	0.01–4.32
Pancreas	1	1	1.14	0.01–6.34
Lung	6	5	1.28	0.47–2.79
Breast	16	19	0.84	0.48–1.37
Cervix uteri	12	5	2.24	1.15–3.91
Corpus uteri	2	3	0.78	0.09–2.83
Ovary	3	3	0.94	0.19–2.75
Skin non-melanoma	10	11	0.93	0.44–1.71
Skin melanoma	10	14	0.69	0.33–1.27
Brain	3	3	1.12	0.23–3.27
Other and unspecified	3	4	0.73	0.15–2.13

<sup>a</sup>Reference: Copenhagen**Table 4** Risk of cancer and period of first employment among Danish male mail carriers

Period of employment	Mail carriers			
	Observed	Expected <sup>a</sup>	SIR	95% CI
<b>All malignant cancers</b>				
1898–1919	368	386	0.95	0.86–1.06
1920–1929	49	53	0.92	0.68–1.21
1930–1939	262	251	1.04	0.92–1.18
1940–1949	429	492	0.87	0.79–0.96
1950–1959	251	300	0.84	0.74–0.95
1960–1969	161	161	1.00	0.85–1.16
1970–1979	65	67	0.97	0.75–1.23
≥1980	27	35	0.77	0.51–1.12
<b>Lung cancer</b>				
1898–1919	68	75	0.90	0.70–1.14
1920–1929	14	12	1.15	0.63–1.92
1930–1939	53	53	1.00	0.75–1.31
1940–1949	78	95	0.82	0.65–1.03
1950–1959	59	51	1.16	0.88–1.49
1960–1969	23	19	1.19	0.75–1.78
1970–1979	4	6	0.66	0.18–1.70
≥1980	3	2	1.51	0.30–4.40

<sup>a</sup>Reference: Copenhagen

that the mail carriers had a borderline, significantly low risk of skin cancer. Mail carriers in Denmark wear a uniform that covers the body; however, it is optional for them to wear a cap (Plena, Post Denmark, personal communication, 2001). Mail carriers had a significantly low risk of kidney cancer. The fall in SIR was more pronounced for mail carriers who had been employed for more than 20 years. In a recent study it was found that workers in industries with a potential for gasoline or motor exhaust exposure experienced a non-significant excess risk of brain glioma (Zheng et al. 2001). Our study could not confirm these results. The only site for a significant excess cancer risk was the cervix among female mail carriers. In studies of possible aetiological factors for cervical cancer, early age at first intercourse and multiple partners (Kjaer et al. 1996, 1992) were found.

The International Agency for Research on Cancer (2002) recently concluded that there was sufficient evidence in humans of a preventive effect of physical activity on cancers of the colon and breast and limited evidence for cancers of the endometrium and prostate.

**Table 5** Risk of cancer among Danish male mail carriers

	Time since first employment (years)								
	0-14			15-29			30+		
	Observed	SIR <sup>a</sup>	95% CI	Observed	SIR <sup>a</sup>	95% CI	Observed	SIR <sup>a</sup>	95% CI
All malignant	108	1.00	0.82-1.21	273	0.96	0.85-1.08	1,231	0.91	0.86-0.96
Oesophagus	0	-	-	2	0.44	0.05-1.60	13	0.52	0.25-0.89
Larynx	2	1.56	0.17-5.62	5	0.68	0.22-1.59	27	0.99	0.85-1.44
Lung	7	1.12	0.45-2.30	35	0.85	0.59-1.18	260	0.98	0.86-1.10
Bladder	7	1.58	0.63-3.26	17	0.88	0.51-1.41	114	0.98	0.81-1.17
Skin melanoma	17	0.82	0.48-1.32	55	0.92	0.70-1.20	177	0.86	0.74-0.99
Skin non-melanoma	9	0.62	0.28-1.17	47	1.00	0.73-1.33	159	0.86	0.73-1.00
All malignant									
Duration of employment (years)									
<0.25	0	-	-	2	0.47	0.05-1.69	21	1.15	0.71-1.76
0.25-1	13	0.91	0.48-1.56	34	1.11	0.77-1.55	85	0.87	0.70-1.08
1-5	36	1.01	0.71-1.39	39	0.81	0.57-1.10	138	0.90	0.76-1.07
6-19	59	1.06	0.81-1.37	87	1.01	0.81-1.25	149	0.94	0.80-1.10
20+	0	-	-	111	0.96	0.79-1.16	838	0.90	0.84-0.97

<sup>a</sup>Reference: Copenhagen

We found a significant low risk for prostate cancer among mail carriers. Assessments of various periods in life where the physical activity as a mail carrier took place showed no effect on the cancer risk.

Selection factors that operate on groups of employed individuals contribute to the healthy worker effect, in which individuals who are employed are found to be in better health and have lower disease rates than individuals who are not employed (McMichael 1976). However, the mechanisms for selection that result in low disease incidence do not, generally, have much impact on diseases with extended development time, e.g. cancers. The heavy physical requirements placed on mail carriers (Jørgensen et al. 1983) result in a selective turnover in addition to the strict selection that is made when people enter the occupation. Thus, one could assume that the healthy worker effect could be of great importance in this study in which one has to have a relatively good physique to handle the job. Moreover, mail carriers who are sick or old are employed inside a post office. Normally, the healthy worker effect tapers off with time since entering into the cohort. However, when allowing 30 years of latency time to pass we see that the cancer rates for all malignancies are significantly low.

Hernberg has suggested three criteria by which the validity of so-called negative studies can be judged (Hernberg 1981). Such studies should (1) possess sufficient statistical power to detect a difference if it exists, (2) define precisely the exposure under study and (3) define experimental and reference groups so as to optimise comparisons. This study fulfils the requirements with regard to the cohort size, the length of the follow-up period and the frequency of the disease under investigation. The exposure level was not uniform over the entire study period, particularly since the duration of employment varied from a few days to more than 40 years. This might have diluted the estimation of effect

and subjected the results to a type II error. However, the substitution of duration for dose was necessitated by the lack of more specific knowledge with regard to levels of environmental contaminants and with regard to the occupational risks associated with mails carrying. The selection of the population of Copenhagen as a reference group in this study was preferred to that of the country as a whole, since it shared a similar geographical, social and cultural environment. The large denominator this population provided, assured stable rates of mortality for the computation of the expected number of deaths.

The epidemiological evidence suggests that air pollution contributes to the occurrence of lung cancer among the general population. In this study of mail carriers, who spent half their working day doing hard physical work outside in the air pollution, we saw no excess risk for cancers related to air pollution as compared with the general population of Copenhagen.

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